

**ESPC Coupled Global Prediction System -
Develop and Test Coupled Physical Parameterizations:
NAVGEN/CICE/HYCOM**

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LONG-TERM GOALS

A fully coupled global atmosphere/wave/ocean/land/ice prediction system providing daily predictions out to 10 days and weekly predictions out to 30 days.

OBJECTIVES

The initial operational capability of a fully coupled global atmosphere/wave/ocean/land/ice prediction system is targeted for 2018. Predictions will provide environmental information to meet Navy and DoD operations and planning needs throughout the globe from undersea to the upper atmosphere and from the tropics to the poles. The system will be implemented on Navy operational computer systems, and the necessary processing infrastructure will be put in place to provide products for the Navy fleet user consumption.

APPROACH

Building on the ESMF NUOPC interoperability layers, present advanced models representing the physics within each of the earth components of atmosphere, ocean, surface waves, ice and land will pass information through separate flux computation models. The system will use analysis fields of each component as initial conditions and make daily forecasts out to 10 days. Throughout each weekly cycle, predictions out to 30 days will be constructed.

Task 1). Implementation of coupling physics between NAVGEN/HYCOM/CICE.

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WORK COMPLETED

At the start of this project, HYCOM and CICE have already been coupled using the Earth System Modeling Framework (ESMF) with atmospheric forcing input from files and the results validated. Summer seasonal forecasts (out to 5 months) have been run as part of the Study of the Environmental Arctic Change (SEARCH) Sea Ice Outlook (SIO) effort. The SIO is an international effort to provide a community-wide summary of the expected September arctic sea ice minimum. Monthly reports released throughout the summer synthesize community estimates of the current state and expected minimum of sea ice.

Along with the backbone components of this system (NAVGEN/HYCOM/CICE), other data models have been used to read archived atmospheric data, ocean data and other observed data. Figure 1 shows a system of CICE coupled with Data_Atmos and Data_Ocean. Figure 2 shows a system of CICE coupled with Data_Atmos, Data_Ocean and Data_Assim (assimilation).

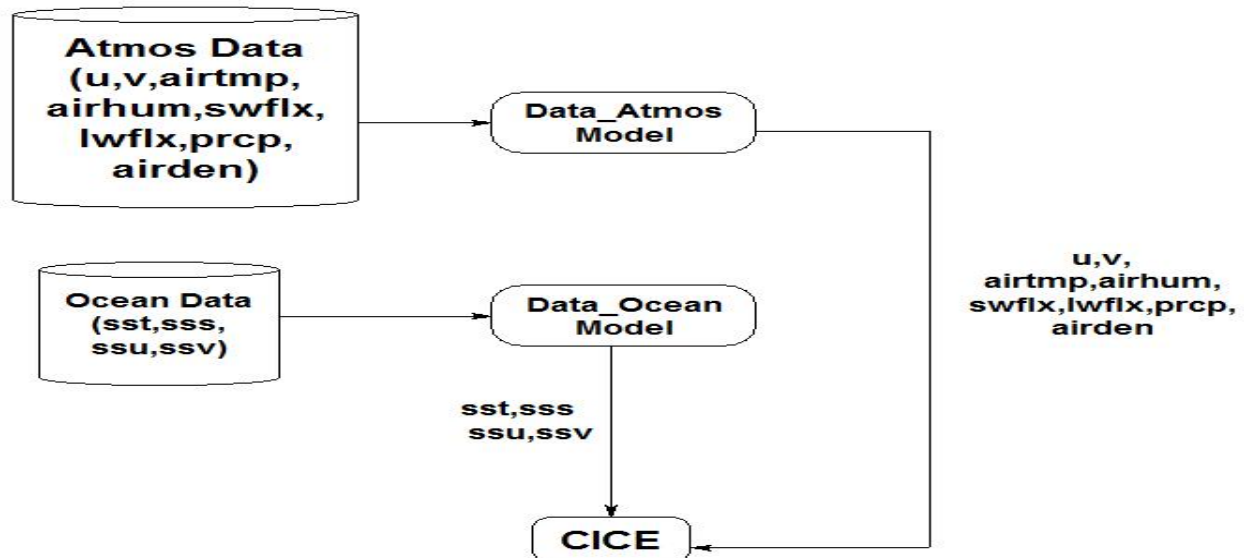


Figure 1. A system of CICE coupled with Data_Atmos and Data_Ocean.

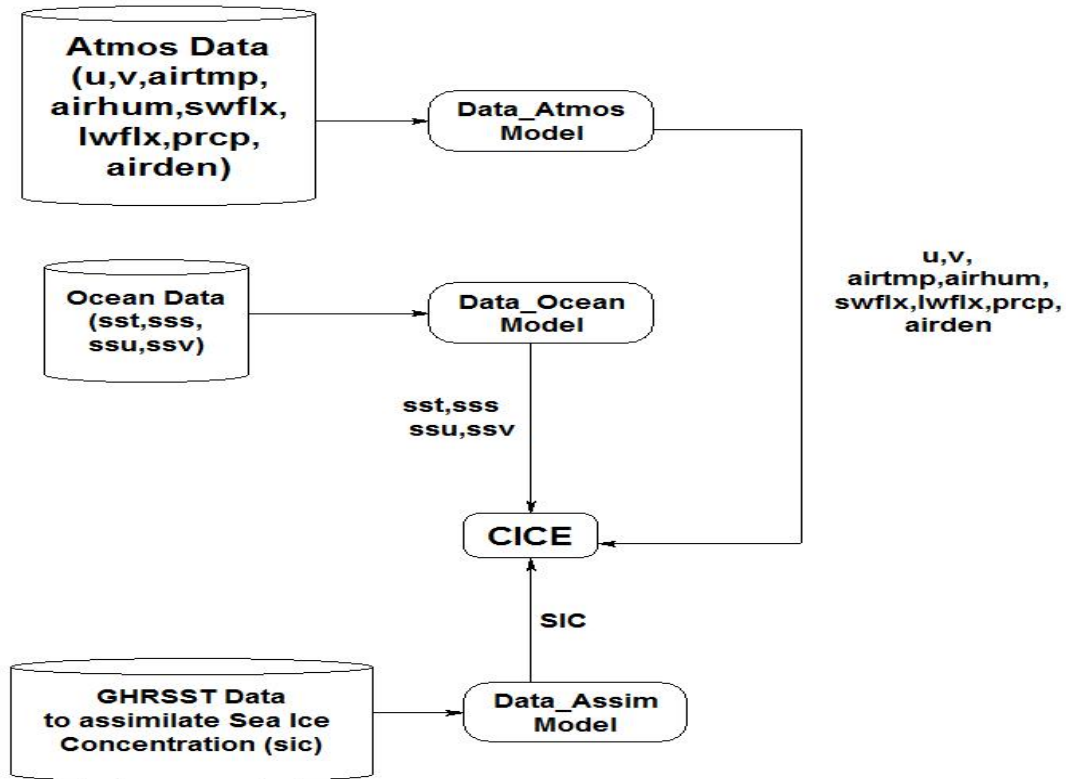


Figure 2. *A system of CICE coupled with Data_Atmos, Data_Ocean and Data_Assim (assimilation).*

RESULTS

In May 2013, the Arctic Cap Nowcast/Forecast System (ACNFS), i.e. coupled HYCOM/CICE, was run in forward model mode, without assimilation, initialized with a May 1, 2013 analysis to determine a seasonal projection of September Arctic sea ice minimum. Eight model runs were made, using Navy atmospheric forcing from 2003-2012 and run forward for 5 months for each specific year. This ensemble of eight members gives an indication of how sea ice can respond to variable atmospheric conditions during summer. Ice extent was calculated using all grid cells with at least 15% ice concentration and then averaged over each day in September. Ice extent averaged across all ensemble members during September was the September ice extent estimate. For the runs initialized from May 01, 2013, the ACNFS outlook sea ice extent estimate was $4.9 \text{ Mkm}^2 \pm 0.7 \text{ Mkm}^2$. Figure 3 shows the distribution of the individual Pan-Arctic Outlook values (June report) for September 2013 sea ice extent. The 2013 sea ice minimum was 4.81 Mkm^2 observed on September 13.

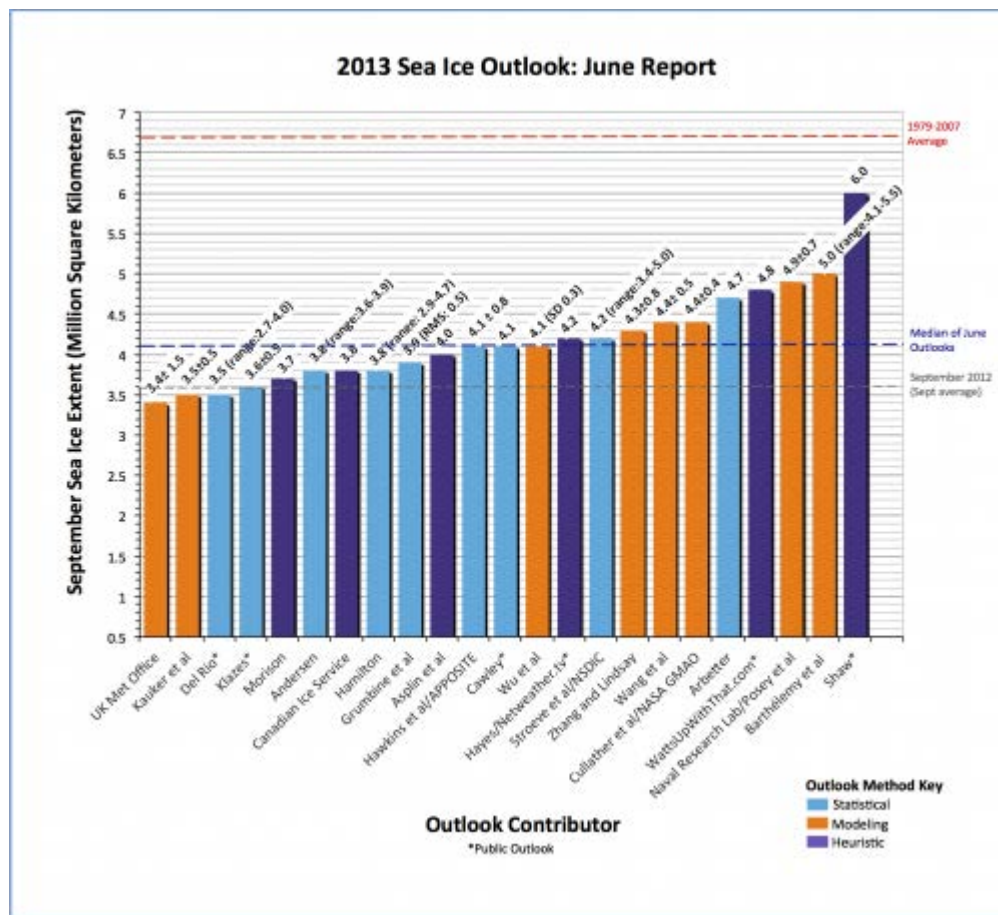


Figure 3. Distribution of individual Pan-Arctic Outlook values (June Report) for September 2013 sea ice extent (values are rounded to the tenths).

We have also tested a single column model of the arctic surface flux parameterization. It uses the mosaic method to calculate the fluxes in summer conditions where sea ice and melting ponds may co-exist. Tests show that the heat and moisture roughness are sensitive to the sea surface conditions. Figure 4 shows that both the momentum and scalar roughness lengths are strong functions of wind speed over sea ice. The ratios of the scalars to the momentum roughness are also dependent on the surface dynamic condition. Conventionally, the roughness lengths are specified as constants in the numerical models such as in GFS and COAMPS; this relationship should be correctly modified in both the ESPC efforts and within the operational NAVGEM system according to the new understanding.

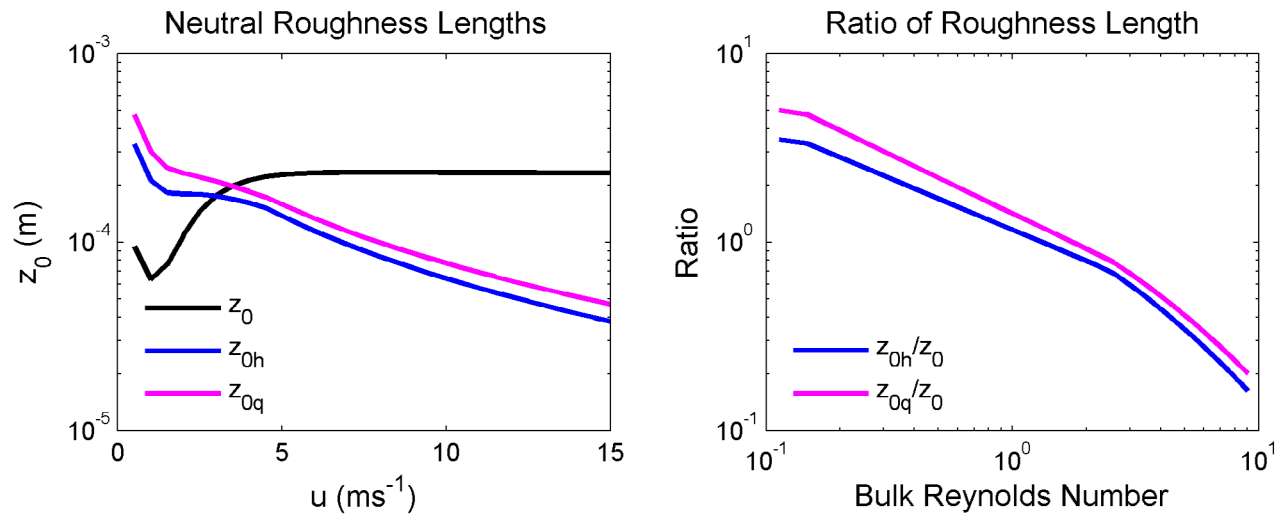


Figure 4. Representation of surface roughness over sea ice following Andreas et al. (2010). Left: roughness of momentum (z_0), heat (z_{0h}) and moisture (z_{0q}) as a function of wind speed; right: the ratio z_{0h}/z_0 or z_{0q}/z_0 as a function of the bulk roughness Reynolds number.

An example of a coupled run product from the Data_Atmos-Data_Ocean-CICE system (Figure 1) is shown in Figure 5, in which contours of sea ice concentration (SIC) and sea surface temperature (SST) at the end of 1440 hrs (60 days) are displayed. To validate with the observed data, we use GHRSSST analyzed SIC for comparison as shown in Figure 6. In general, at the end of the two month spin-up simulation, CICE can generate a result which is in good agreement with the observed GHRSSST SIC data.

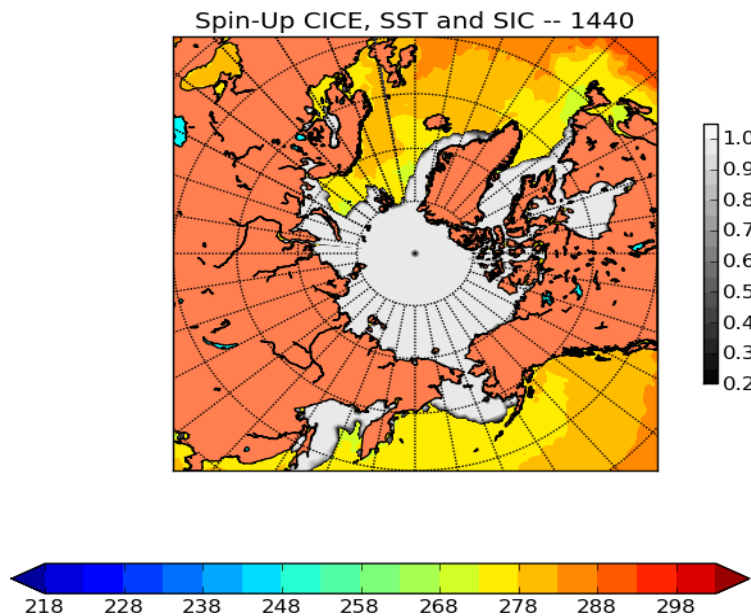


Figure 5. 1440 hour (60 day, from 01 Jan 2010) sea ice concentration (SIC) simulated by the Data_Atmos-Data_Ocean-CICE system.

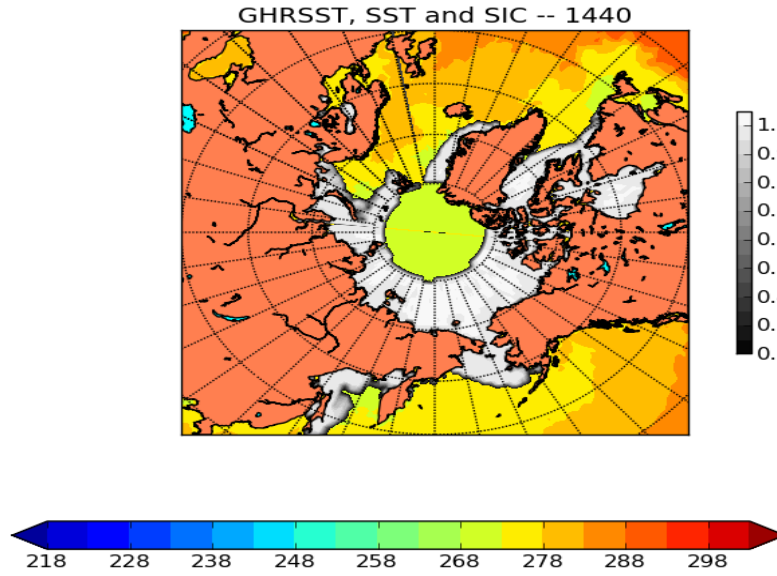


Figure 6. *GHR SST Sea Ice Concentration (SIC) analysis. The display time is the same time as that in Figure 5.*

Using the four-model system (Data_Atmos, Data_Ocean, Data_Assim and CICE – shown in Figure 2), a spinup for sea ice using NOGAPS and HYCOM archived historic data are employed to drive CICE. Moreover, we use GHR SST analyzed sea ice concentration (SIC) data to assimilate sea ice into CICE via Data_Assim model. The assimilated result is shown in Figure 7.

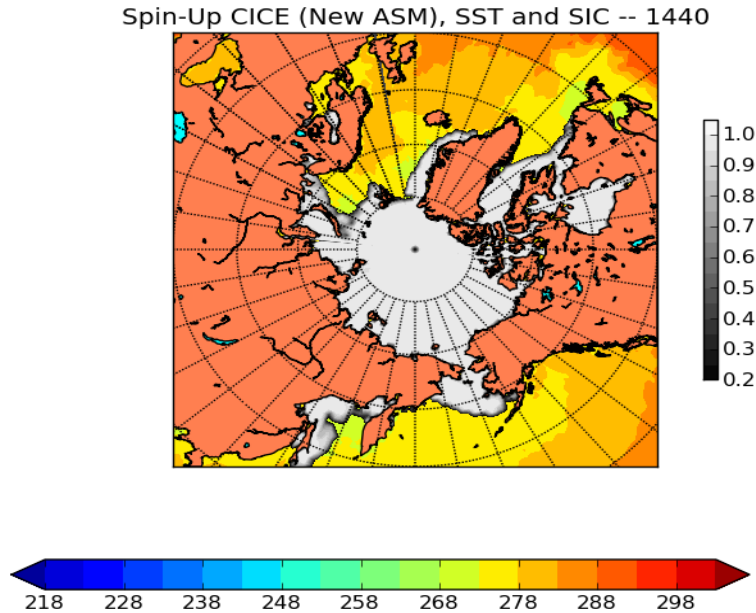


Figure 7. *Same as in Figure 5, except the run assimilated GHR SST analyzed sea ice concentration.*

Note, the corresponding non-assimilated case is shown in Figure 5. To compare with the GHR SST observed sea ice concentration data (Figure 6), we found that the assimilated case has done its job which is better than that of the non-assimilated case.

The plan is to use the CICE restart file generated by the ice spin-up procedure (using the Data_Atmos-Data_Ocean-CICE system) as the initial condition for the NAVGEM-Data_Ocean-CICE or NAVGEM-HYCOM-CICE systems to conduct forecasts.

IMPACT/APPLICATIONS

Surface heat fluxes and winds must be exchanged between NAVGEM, HYCOM and CICE. The fluxes and winds must be implemented for ESPC through the NUOPC interoperability layer. Consideration of flux computations from both the atmosphere and the ice perspectives must be taken into account and move toward consistent flux computations. Additional effects will also be added, including variations in albedo and roughness on wind drag.

RELATED PROJECTS

The five other subprojects in ESPC project:

- 1) Coupling infrastructure and interoperability layer extension across all earth components
- 2) Develop and test coupled physical parameterizations: NAVGEM/HYCOM
- 3) Develop and test coupled physical parameterizations and tropolar wave model grid: NAVGEM/WaveWatch-III/HYCOM
- 4) Aerosol Physical Coupling
- 5) Development of ESMF for coupling capability (NOAA/ESRL)

REFERENCES

Andreas, E.L., T. W. Horst, A. A. Grachev P. O. Persson, C. W. Fairall, P. S. Guest, and R. E. Jordan, 2010, Parameterizing turbulent exchange over summer sea ice and the marginal ice zone. *Q. J. R. Meteorol. Soc.* 136: 927–943.

PUBLICATIONS

P.G. Posey, E. J. Metzger, R. A. Allard, R. H. Preller, D. Hebert, A.J. Wallcraft, M.W. Phelps, and O. M. Smedstad, “Arctic Cap Nowcast Forecast System (ACNFS) End of Summer 2013 Ice Extent Projection- June Report”, Sea Ice Outlook Project website, posted Jun, Jul, Aug and Sept, 2013.